VENTILATION-AIR HEATING PLANTS OF THE MENOMINEE RANGE

By Walter E. Lewis

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Walter E. Lewis[1/]

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INTRODUCTION AND SUMMARY

Ventilation-air heating plants are in use at several iron mines on the Menominee Iron Range, Iron River, Mich. Many of the mines are exceptionally wet; during winter months, when fresh air is forced down the wet air shafts into the mine, it is usually necessary to heat the fresh air to above freezing so that the openings will not be closed by ice.

The problem of ice closing air shafts has been solved by the practice of reversing the air current before the openings have become completely closed. This procedure involves drawing warm air from the mine up the usual down-draft air shaft. The M. A. Hanna Co. has found, at some of their mines on the Menominee Range, that it is more convenient to heat the below-freezing air rather than reverse the air current. Intermittent freezing and thawing of ice that has formed in the air shaft tends to loosen the wall rock, requiring major shaft repairs. The openings are kept free of ice the year around by heating the fresh air during periods of below-freezing weather. Table 1 shows the monthly minimum mean, maximum mean, and mean temperatures for the Iron River area. Under normal conditions of temperature, the furnaces are fired in November and usually are not allowed to go out until April of the following year.

Two main types of ventilation-air heating plants are in use by the M. A. Hanna Co. - steam and hot air. In both types of plants heat is supplied by coal.

Each plant discussed is slightly different in details of design, method of heating the cold air, and method of operation; also, each type of plant services underground workings that are different in some respects. The plant at the Homer mine is a hot-air plant and supplies fresh air to a main air course, from which it is then forced to the various workings by secondary and auxiliary fans. The steam plant at the Bengal mine services the mine in the same way. The plant at the Hiawatha No. 1 mine is a hot-air plant. It supplies fresh air to a main air course; but the air also enters abandoned stopes, which serve as air-storage chambers.

In the steam-heat type of plant, fresh cold air is drawn through steam-heated coils and forced into the wet air shaft by a main centrifugal fan in blower position to the mine. The hot-air-type plants require two fans - a main fan in blower position to the mine with exhaust position to the furnace and an accessory fan in blower position to the furnace. The accessory fan forces cold air into the circulatory ducts of the hot-air furnace. The air emerges heated and mixes with cold air being drawn into the main fan. The main fan in turn draws the intermixed cold and heated air and forces it into the air shaft. The primary purpose of the accessory fan in the hot-air plants is a safety measure to maintain positive pressure in the furnace circulatory ducts, so that in case of rupture of the ducts of the furnace, furnace soot, ashes, and smoke will not be forced into the mine by the main fan.

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TABLE 1. - Average monthly temperatures, Iron River, Mich.[1/]

Month	Average temperature, °F.	Average maximum temperature, °F.	Average minimum temperature, °F.	Highest temperature, °F.	Lowest temperature, °F.	Remarks
January..	10.6	21.0	0.2	53	-43	Furnace in operation.
February.	11.7	23.2	.3	64	-47	Do.
March....	24.2	36.0	12.4	83	-30	Do.
April....	39.1	52.1	26.3	85	-12	
May.....	51.2	65.1	37.2	94	10	
June.....	60.6	74.6	46.4	98	23	
July.....	65.1	79.2	51.1	100	28	
August...	62.5	76.7	48.3	94	26	
September	55.3	68.7	42.0	96	15	
October..	44.0	55.7	32.3	84	4	
November.	30.0	39.4	20.6	70	-17	Furnace in operation.
December.	16.7	26.2	7.3	56	-34	Do.

1/ U. S. Dept. Agr., Weather Bureau, Climatic Summary of the U. S., Section 63, Upper Michigan, pp. 18-19.

The plants have all been built to rigid safety specifications and provide for quick reversal of air current in case of fire or other emergency. Floor drains have been provided to facilitate removal of water that may accumulate by condensation or otherwise, bird screens are placed over the fresh-air intakes, and a positive pressure is always maintained in the circulatory ducts of the hot-air furnaces.

Each plant, whether hot-air or steam, is designed for the particular needs of the mine it serves, but in all cases to provide the necessary amount of warm air to keep the air shaft open. The number and type of electrically controlled automatic devices on the plants are determined by the mine to be served. Manually controlled heating plants are completely satisfactory in some cases. In mines where the air is blown into large storage chambers or where decreasing the amount of fresh air entering the mine over a short period does not impair working efficiency, "starving" the fan for air has been found to be a satisfactory method of reducing the amount of cold air entering the wet air shaft.

The purpose of this report is to cover the operating idea rather than to discuss the technical details of design and air flow. The heating plants described were designed by the technical staff of The M. A. Hanna Co. They were assisted in the installation of automatic devices by technical men from various equipment manufacturers. Technical details of design, as well as details of the design and installation of automatic devices, are available from fan and furnace manufacturers.

ACKNOWLEDGMENTS

The cooperative efforts of the following officials and employees of The M. A. Hanna Co. at Iron River, Mich., are gratefully acknowledged:

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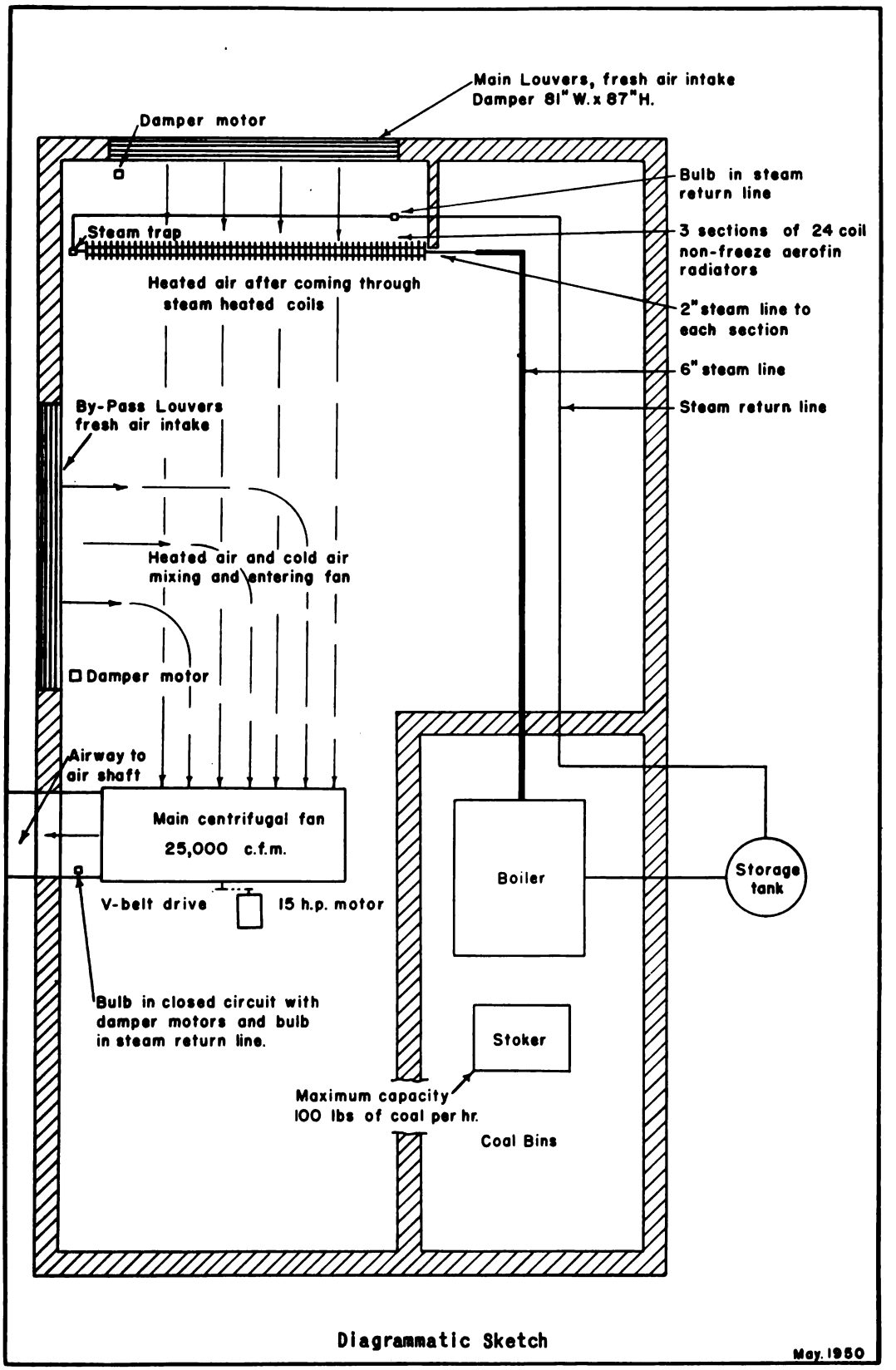
Main Louvers, fresh air intake
Damper 81" W. x 87" H.
Damper motor
Bulb in steam return line
Steam trap
3 sections of 24 coil non-freeze aerofin radiators
Heated air after coming through steam heated coils
2" steam line to each section
6" steam line
Steam return line
By-Pass Louvers fresh air intake
Heated air and cold air mixing and entering fan
Damper motor
Airway to air shaft
Main centrifugal fan
25,000 c.f.m.
V-belt drive
15 h.p. motor
Boiler
Storage tank
Bulb in closed circuit with damper motors and bulb in steam return line.
Stoker
Maximum capacity
100 lbs of coal per hr.
Coal Bins
Diagrammatic Sketch
May. 1950

Figure 1. - Steam heating plant, Bengal mine.

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S. E. Quayle, manager, Michigan mines
George Koehler, chief mining engineer
R. C. Mahon, superintendent, Homer and Wauseca mines
Charles Haines, master mechanic, Homer and Wauseca mines
R. B. Wortley, superintendent, Hiawatha No. 1 and 2 mines
Aden Krans, chief mechanic, Hiawatha No. 1 and 2 mines
Jack Morrow, mining engineer
Frank Keese, superintendent, Bengal mine
Jack Corlette, electrician, Bengal mine

Most of the data presented herein have been gained through personal conversation and discussion with Mr. Koehler and the respective mine superintendents and mechanics. Acknowledgment is also made to G. M. Kendrick of the American Blower Corp., for his suggestions and criticisms on the portion of the paper concerned with the scoop control hydraulic coupling.

BENGAL MINE PLANT

The steam heating plant at the Bengal mine is semi-automatically operated. The plant was designed to maintain the fresh air entering the airway during the winter at 40° F. or above.

General features in the design of the plant are: 1. Fresh air required by the mine is furnished by a main centrifugal fan having rated capacity of 25,000 c.f.m. in blower position to the mine. 2. The temperature of the fresh air entering the mine is controlled by a temperature-registering bulb installed in the exhaust airway of the main centrifugal fan. 3. The plant is built to rigid specifications of safety and provides for quick reversal of the air current in the case of fire or other emergency.

Air is forced underground through a direct air course, and distribution from there is by secondary or auxiliary fans.

Figure 1 is a diagrammatic sketch of the plant and shows the direction of air flow. Both furnace and fan are completely enclosed in separate steel buildings. Coal is stored in bins and fed to the furnace by a manually controlled stoker. The stoker feeds the furnace that heats the water in the boiler and transforms it into steam. Water is obtained from a local city supply. The stoker has a maximum capacity of 100 pounds of coal per hour, but the maximum is not needed except during periods of extremely low outside temperature. The amount of coal required to heat the incoming air is dependent on the outside temperature and is determined by the operator. An experienced operator usually can estimate closely the amount of heat required for various outside temperatures.

Steam generated in the boiler passes through a 6-inch steam line to the Aerofin steam radiator unit. The radiator unit consists of three sections in a vertical position, one upon the other. Two-inch steam lines branch from the main 6-inch line to service each section of the radiator unit. The steam passes through the radiators into a steam trap, condenses, and returns to the water-storage tank. Appropriate valves and connections are included in the circuit where needed.

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Fresh air is furnished to the mine by an electrically driven centrifugal fan driven by a V-belt drive from a 15-hp. motor. It supplies 25,000 c.f.m. at 889 r.p.m. The fan draws fresh air from two sources: (1) through by-pass louvers, which are in front of the steam-heated radiators, and (2) through main louvers, which are in back of the steam-heated radiators. The fresh air drawn from outside through the by-pass louvers is not heated. Air from both sources is drawn simultaneously into the main centrifugal fan and forced into the airway, which in turn carries it into an airshaft.

A thermometer in the airway at the exhaust side of the main centrifugal fan automatically controls the size of the openings in the fresh air intake louvers and keeps the air entering the mine at approximately 40° F. The thermometer is connected in closed circuit with (1) an electric motor that operates dampers on the by-pass louvers, (2) another electric motor that operates dampers on the main louvers, (3) an alarm bell, and (4) a thermometer in the steam return line.

The airway thermometer operates the dampers on both sets of louvers by means of controllers. If the temperature of the air in the airway drops below 40° F., the bulb reacts to the lower temperature and starts the electric motors that operate the dampers on both sets of louvers. The by-pass louver dampers would then start to close, and the main louver dampers would gradually open, thereby introducing more air through the steam-heated radiator unit and serving to raise the temperature in the airway. When the temperature reaches 40° F., the thermometer in the airway is stabilized and the motors are cut off.

Conversely, as the temperature of the air is raised above 40° F. in the airway, the thermometer, by means of the controller, starts the louver damper motors. The by-pass louver dampers will then open wider, and the main louver dampers will gradually close. When the temperature again reaches 40° F., the motors will cease to operate.

When the outside temperature is above 40° F., it is not necessary to heat the air, and all air enters through the by-pass louvers. In extremely cold weather the by-pass louver dampers may be completely closed and the main louver dampers may be completely open; thus, all cold air will pass through the radiator unit. If the operator is fully aware of the situation and has the furnace operating at peak capacity, the radiator coils will not freeze; but if the furnace is not generating enough steam and the coils freeze, the alarm bell will indicate that a section of the radiator unit has frozen. This alarm is activated by the thermometer in the steam return line.

When the plant was first designed in 1948, it was without by-pass louvers, and temperatures were controlled by shutting off the steam to a section in the radiator unit by means of a "kick-off" valve on the 2-inch steam line. The fresh air would then pass through two heated sections and one cold section. All sections were equipped with "kick-off" valves, and if the air was sufficiently warm, all sections would eventually be shut off from the circuit. Conversely, if the temperature in the airway dropped lower than 40° F., one or more sections would automatically be cut back into the circuit, so the fresh air would pass through heated sections.

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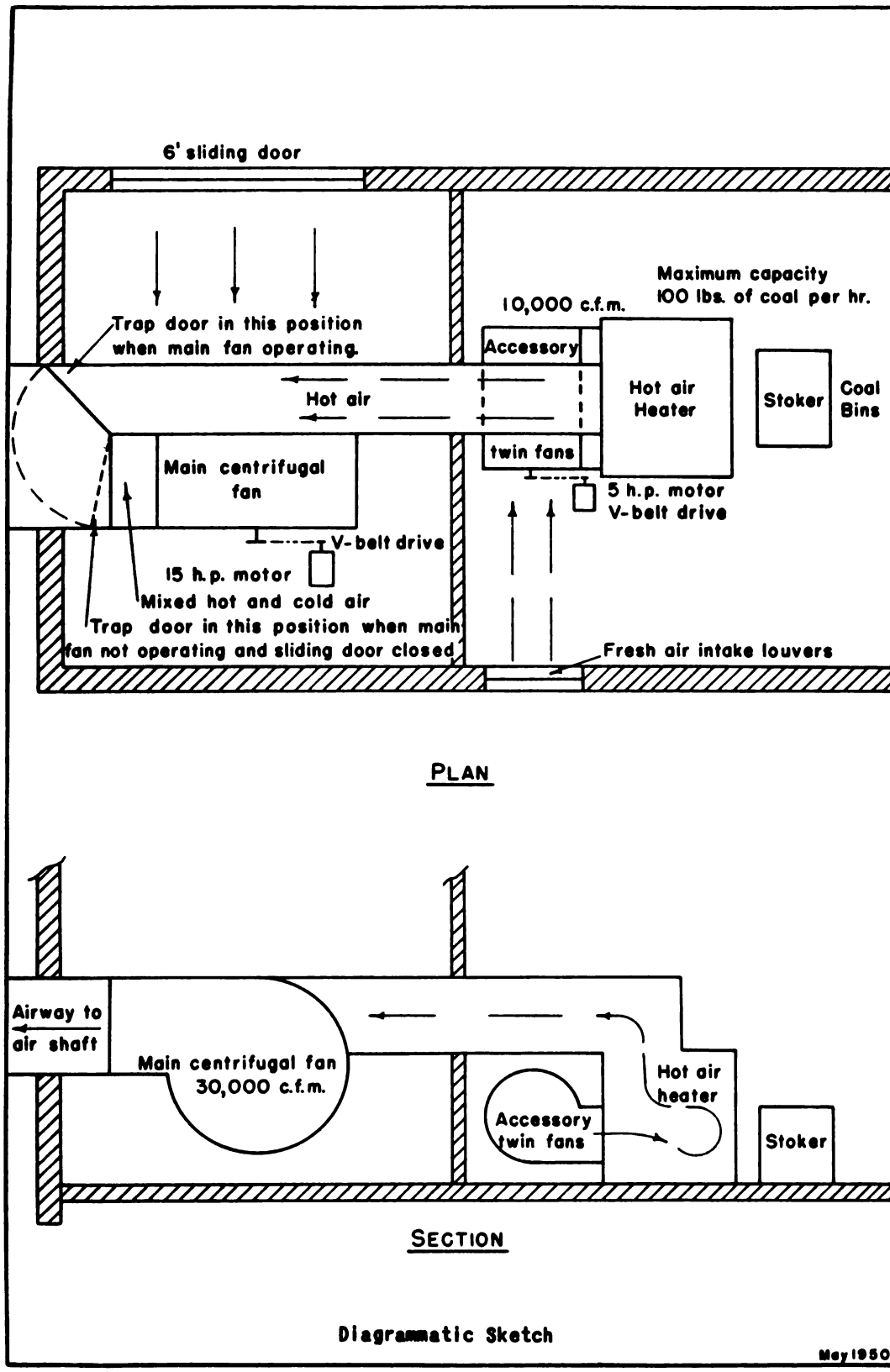

Figure 2. - Hot-air plant, Hiawatha No. 1 mine.

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Although this method served to control the temperature satisfactorily, it was soon realized the cold fresh air condensed the steam in a shut-off section. The water and the coils then froze, and this necessitated shutting down the fan to thaw the frozen section.

This situation was partly solved in the winter of 1948-49 by by-passing the steam around the "kick-off" valves in the 2-inch lines with a 1-inch steam line. This permitted steam to enter each section continuously, even if the "kick-off" valve was closed, although not in as great quantity as through the 2-inch line. The steady but small amount of steam moving through the section was enough to keep the sections from freezing.

In the summer of 1949, the "kick-off" valves were removed completely and by-pass louvers installed. Now the steam enters all sections constantly from pipes of the same diameter, and temperature is controlled by the automatically controlled dampers on the by-pass and main louvers.

The plant has operated successfully under the design with the by-pass and main louvers through the winter of 1949-50 in temperatures that have approached a minus 30° F. Freezing of coils has been eliminated, and good temperature control of the air entering the air shaft has been maintained.

HIAWATHA NO. 1 MINE PLANT

The hot-air heating plant at the Hiawatha No. 1 mine is manually operated

It is so designed that (1) the fresh air for the mine is furnished by a main centrifugal fan, having a capacity of 30,000 c.f.m., located in blower position to the mine and exhaust position to the furnace; (2) twin accessory fans with a capacity of 10,000 c.f.m. are in blower position to the furnace; (3) cold air entering the mine, during wintertime operation, is controlled manually by opening and closing a 6-foot sliding door; and (4) built to rigid specifications of safety, this plant also provides for quick reversal of air current.

Fresh air enters the mine through a 6-foot 4-inch by 6-foot 4-inch shaft. The air currents enter a direct air course as well as large areas that serve as fresh air storage chambers.

The main fan is used alone during the summer months. In wintertime, when outside temperature is low, the twin accessory fans are used in conjunction with the main fan or alone. Their main purpose is primarily to keep positive pressure in the furnace ducts for safety. If no accessory fans were used during furnace operation, the main fan would draw air through the furnace; then, a negative pressure would develop in the furnace ducts. Under such conditions, soot and furnace gases could be drawn into the circuit should a break develop in the walls of the furnace.

The plant is designed so that automatic stokers start when the temperature reaches 32° F. Fresh-air intake for the main fan is through a 6-foot sliding doorway, and adjustment of the opening is controlled manually. The cold fresh air is drawn directly to the main centrifugal fan. Figure 2 is a diagrammatic sketch of the hot-air heating plant.

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Fresh-air intakes for the twin accessory fans are through louvers on the opposite side of the building. The cold air is forced through the hot-air heater ducts. The warmed air is then mixed with the cold fresh air and drawn into the main fan. The main fan then forces the mixed cold and heated air into an airway and thence into the shaft.

Coal for the furnace is stored in bins and fed by an automatic stoker having a peak capacity of 100 pounds per hour. The furnace is rated at 1,255,000 B.t.u. per hour.

The manually controlled sliding door is opened or closed according to the temperature of the air entering the airway at the discharge end of the main fan. It is always kept above 32° F. When the outside temperature is extremely low, the heater has difficulty in raising the temperature of the air above freezing; then the main fan may be cut off entirely and the fresh air-intake sliding doorway closed. When the main fan is not operating, air enters the shaft from an airway that leads directly from the twin accessory fans. These ducts are controlled by a trap door hinged in the wall and shown in the isometric sketch (fig. 3). The door is in the forward position when the main fan is operating. This permits warm air from the heater ducts to enter the main fan and mix with the cold air being drawn through the sliding door. If the main fan is not operated because of excessively low temperatures, the sliding door is closed completely and the trap door is swung into the back position. This opens the airway leading directly to the accessory fan and closes the airway leading from the main fan.

The plant is so designed that, if the twin accessory fans stop working for any reason, the main fan will cut off immediately. This safety precaution enables the operator always to maintain a positive pressure throughout the circulatory system of the heater. The main fan is driven by V-belt connection to a 15-hp. electric motor. The twin accessory fans also are driven in the same manner by a 5-hp. motor.

HOMER MINE PLANT

This heating plant is the hot-air type, completely automatic and so designed as to maintain entering air at 36° F. or above. It is the most elaborate of the three plants discussed and has the highest capacity of cubic feet of air per minute.

General features in the design of the plant are: 1. Fresh air to the mine is furnished by a main centrifugal fan in blower position to the mine and exhaust position to the furnace, and an accessory fan in blower position to the furnace. 2. Temperature of the fresh air entering the mine is controlled by a thermometer on the outside of the building. 3. Speed of the main fan is regulated by a scoop-control hydraulic coupling. This plant also is built to rigid safety specifications and includes bird screens on the fresh-air intakes, positive-pressure maintenance in the circulatory system of the heater, and provision for quick reversal of the air current.

The Homer mine has a main direct-air course, and all air is diverted and forced from the main air course into stopes and sublevels by means of secondary fans and auxiliary fans. No air is forced out of the main air course and into workings by the main fan.

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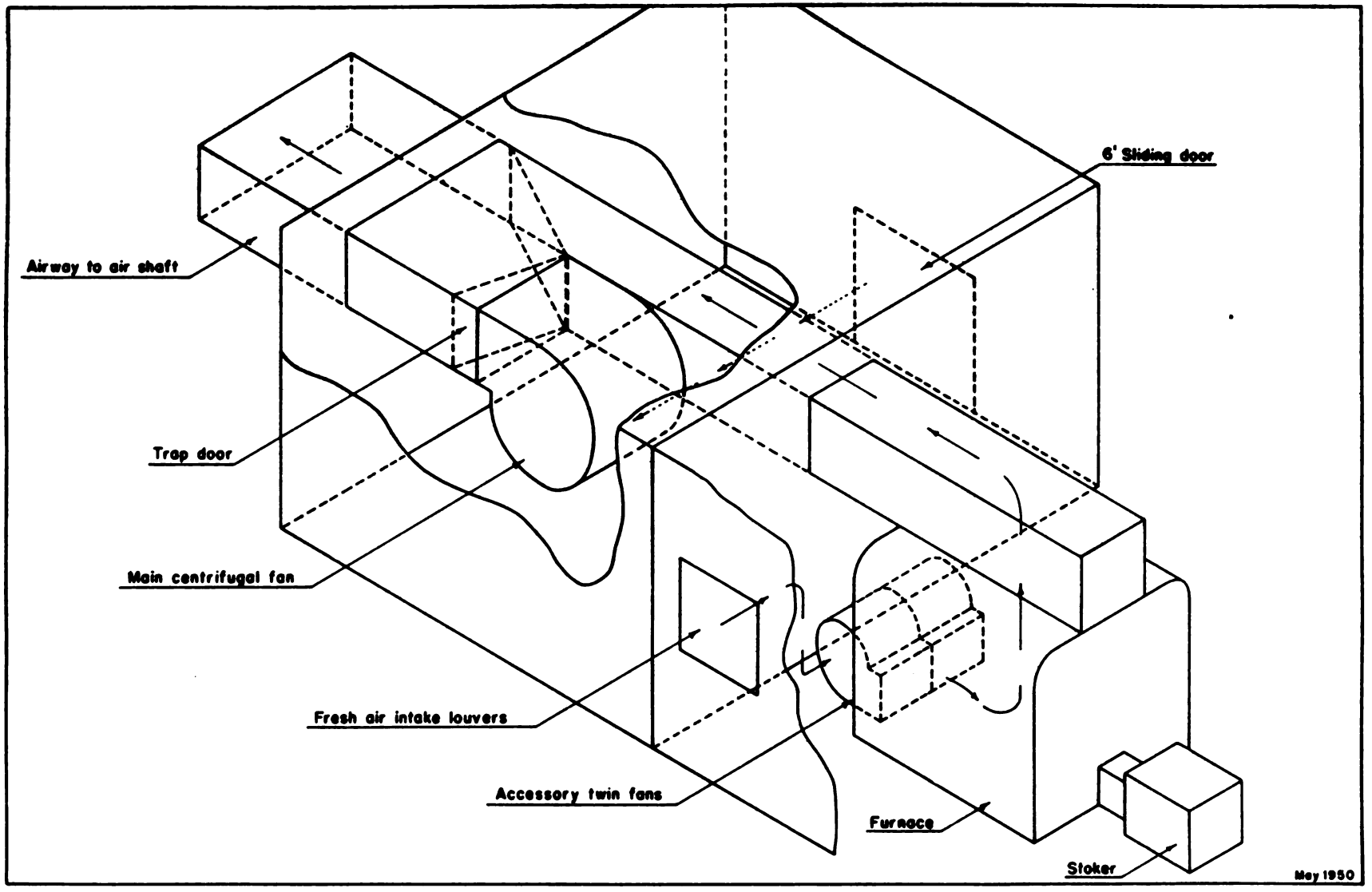

Figure 3. - Isometric sketch of hot-air plant, Hiawatha No. 1 mine.

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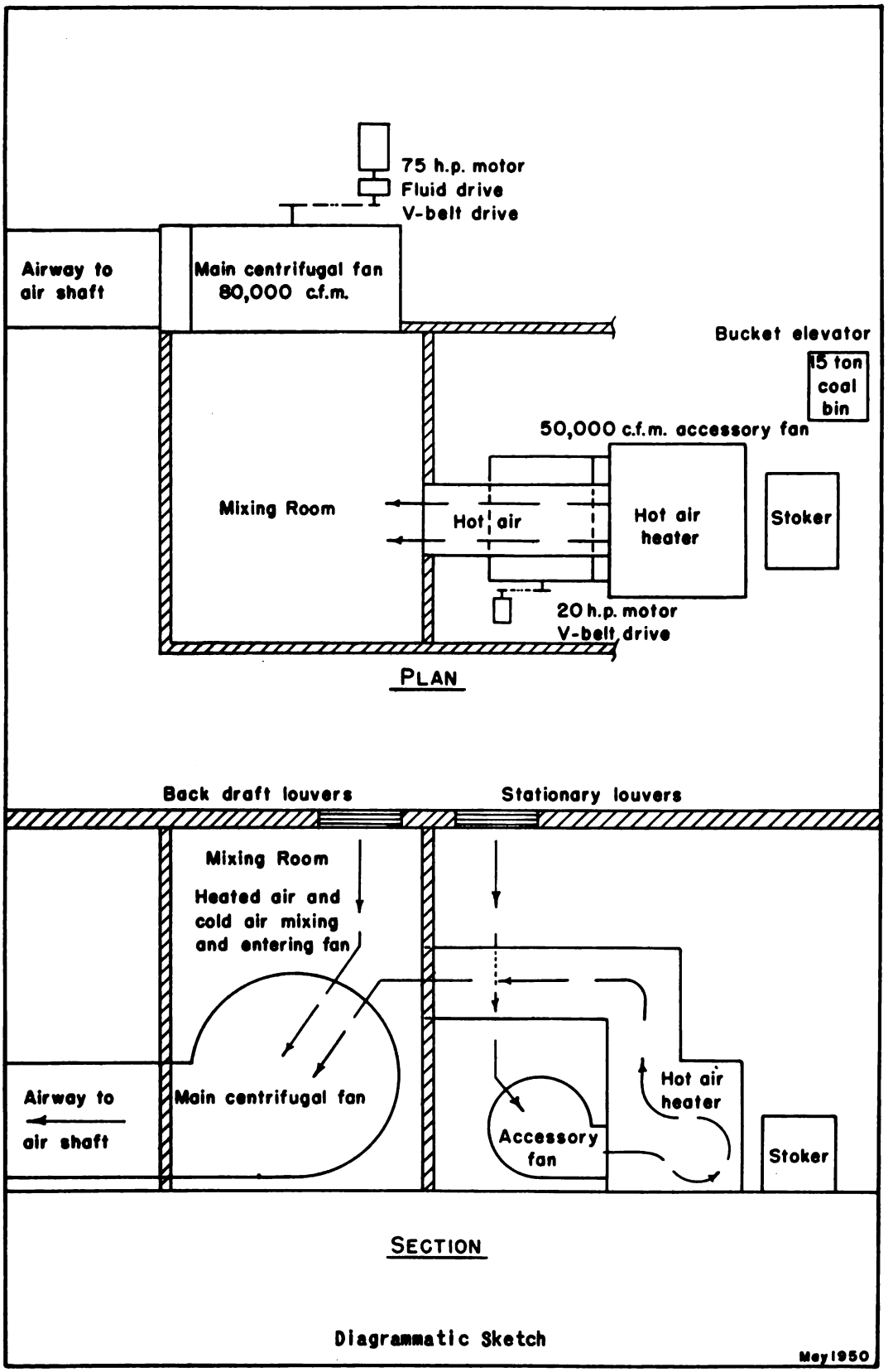

Figure 4. - Hot-air plant, Homer mine.

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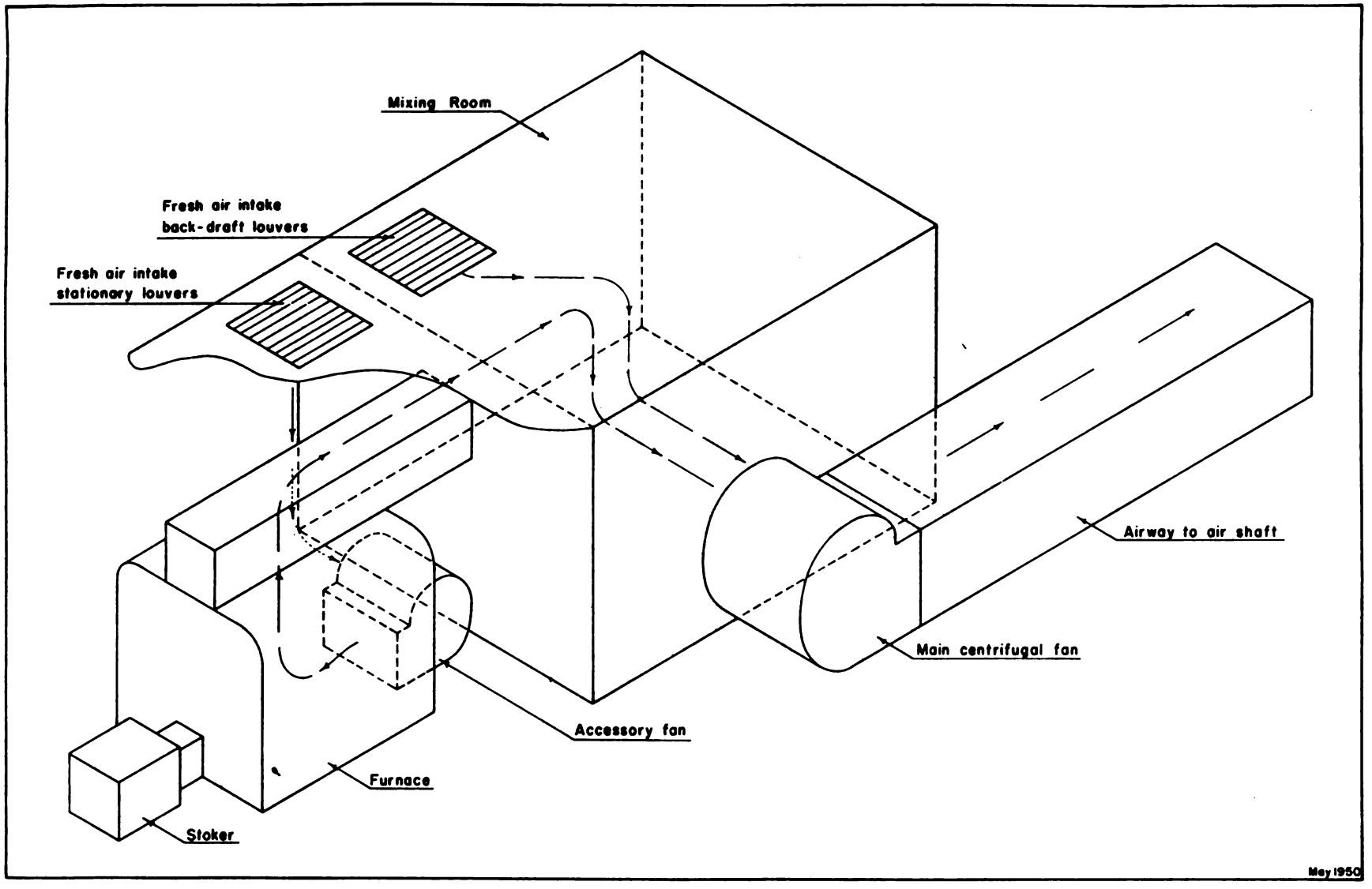

Figure 5. - Isometric sketch of hot-air plant, Homer mine.

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There are no manually operated features in the heating plant other than placing coal in the bins and checking the discharge air for gases. Figures 4 and 5 are a diagrammatic and an isometric sketch of the plant.

The building that houses the plant was formerly a dry house, and it has been built over to fit the needs of the heating plant. The main coal bins are in the basement, and the coal is transferred to a 15-ton capacity stoker-feeding bin by a bucket elevator.

The stoker is equipped with an automatic air feed, which varies the proper amount of air according to the amount of coal fed to the furnace. The furnace is rated at 4,000,000 B.t.u., and coal consumption at maximum capacity is 300 pounds per hour. Stoker operation is controlled by a thermometer in the airway at the exhaust of the main fan. The stoker will start feeding coal at 36° F. and increases or decreases the feeding rate according to the temperature of the air in the airway.

The furnace has an exhaust fan to facilitate removal of gases caused by burning coal. Both the automatic air feed and the exhaust fan are regulated and controlled by the stoker to insure proper combustion of the coal and to assist in gaining the proper amount of CO_2 in the exhaust gases.

The plant is equipped with an 80,000 c.f.m. main centrifugal fan blowing into the mine and a 50,000 c.f.m. accessory centrifugal fan that forces air through the furnace. Each fan has separate fresh air-intake louvers on the roof of the building. The louvers for the main fan are back-draft, whereas those of the accessory fan are stationary. The louver dampers for the main fan are set on pivots; and the size of the opening is determined by the suction of the fan. Air cannot be forced through them from inside the building. The main fan is used alone in summer and with the accessory fan in winter.

Fresh air coming through the louvers for the accessory fan is forced through the circulatory system of the furnace by the accessory fan, and the resulting warm air is mixed in the mixing chamber with the cold air drawn from the fresh-air intakes by the main fan. The main fan, in turn, picks up the intermixed warm and cold air, forces it into the airway, and thence into the airshaft.

The main centrifugal fan has a peak operating capacity of 80,000 c.f.m. and is driven by a constant-speed, 75-hp., 1,800-r.p.m. electric motor through a combination fluid and V-belt drive. Fan speed is controlled automatically by the outside temperature through control of the fluid in the fluid-drive mechanism and is necessary because, at an outside temperature of 20° F., the fan, operating at peak capacity, will freeze the water in the wet air shaft. The 50,000 cubic feet of warm air per minute from the accessory fan is not enough to heat above freezing the 30,000 c.f.m. of cold air drawn in by the main fan; therefore, when the outside temperature is below 20° F., less cold air must be drawn and forced into the air shaft. This is accomplished by slowing the speed of the main fan. For every 10-degree drop in temperature, the fresh air entering the mine is reduced by 10,000 c.f.m.; therefore, at -10° F. only 50,000 c.f.m. enters the mine. This amount of air can then be furnished by the accessory fan, which forces the air through the furnace circulatory system. At temperatures of -10° F. or lower, the

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main fan will idle and move only as a result of the air current created by the accessory fan. The accessory fan then becomes the main fan in the circuit and supplies all fresh air being forced into the mine.

When the temperature outside is low and the main fan is idling, the drive motor continues to run at constant speed owing to the scoop-control hydraulic coupling or fluid drive. The speed of the main fan, regulated by the outside temperature, is controlled in the hydraulic coupling, having an oil capacity of 2-1/2 gallons, and automatically provides stepless speed variation with changes in outside temperature. With the automatically controlled drive, the output speed is proportional to the oil in the working circuit. Minute variation in speed is produced by like adjustments of the scoop lever and is governed by a thermometer outside the building.

The scoop-control hydraulic coupling is shown in figure 6. Drive-shaft speeds are varied by varying the quantity of oil in the working circuit. The oil reservoir is of sufficient diameter that the quantity of oil required by the working circuit for maximum speed and efficiency is contained in a ring of oil rotating outside the working circuit. The scoop tube, which picks up the oil and transfers it to the working circuit of the hydraulic coupling, can be placed in various positions, depending on the quantity of oil required for certain speeds.2/

The fluid drive consists of an impeller and runner, two enclosing casings to retain the oil, and a scoop-tube assembly attached to a stationary manifold. The impeller rotates with the constant-speed driving motor and and thereby pumps oil into the runner, whose vanes absorb kinetic energy from the moving oil. The oil, having given up its energy, then flows toward the center of the runner and passes back into the impeller. The cycle repeats and results in a continuous flow of energy from the impeller side to the runner side. The casings are attached to and rotate with the impeller, and a portion of the oil constantly flows from the inner to the outer casing. Initially, the drive is filled with just enough oil to fill the impeller, runner, and cooling circuit, so that idle oil in the outer casing is a subtraction from the working circuit.3/

The position of the movable scoop tube controlled by the thermometer outside the building adjusts the amount of oil in the outer casing and thus regulates the quantity of oil in the working circuit. The scoop tube can be fully engaged where it skims off all the oil in the casing and thus fills the working circuit, or it can be retracted completely where all the oil lies idle in the outer casing. In this case, the unit is "declutched." In-between positions regulate torque and speed of the drive, thus regulating speed of the fan.4/

At outside temperatures of 20° F. or above, the tube is fully engaged in an upright position and draws all of the oil from the outer ring or reservoir and returns it to the working circuit. Below 20° F. temperatures, the scoop retracts and draws less oil from the reservoir, thereby "starving" the working circuit. As a result, the impeller, rotating with the constant-speed driving

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2/ Edmonsen, G. V., Applying Fluid Drive in Industry: Paper presented before the Detroit Session of AISE Annual Meeting, Sept. 24, 1945. Reprinted from Iron and Steel Engineer, March 1946, by American Blower Corp.

3/ See footnote 2.

4/ See footnote 2.

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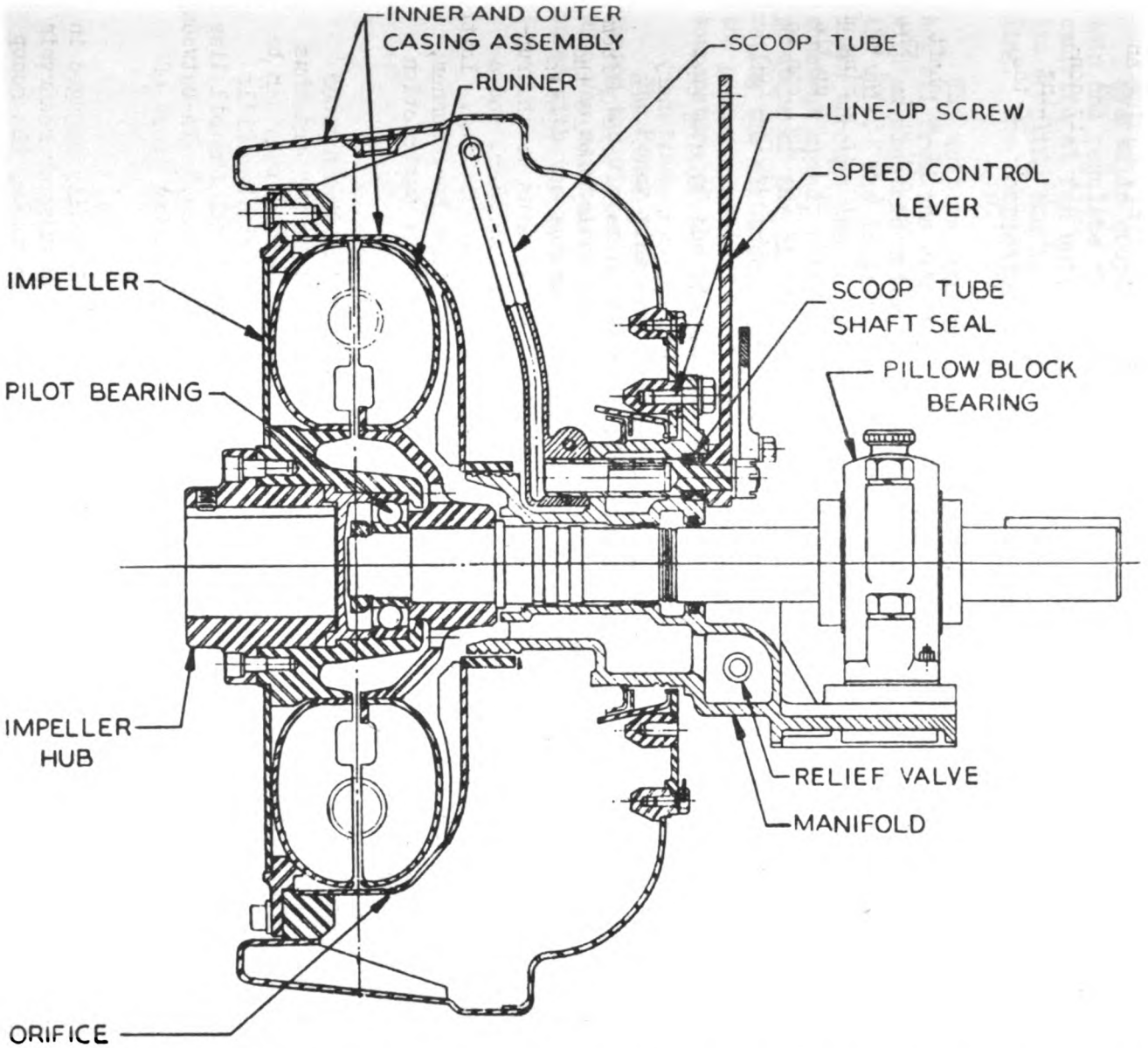

Figure 6. - Scoop-control hydraulic coupling. (Courtesy, American Blower Corp.).

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motor, has less oil to pump into the runner. Power transmission is gained through weight of the fluid and its velocity impingement on the runner vanes; thus, the shortage of oil causes a drag in the runner, or "slippage" results between the impeller and runner. With the scoop tube remaining steady in any intermediate position, "slippage" will be constant, and the fan speed will slow up accordingly.

Hydraulic coupling fluid must be kept at a constant temperature to maintain and regulate the speed control. This is accomplished by employing a centrifugal fan unit cooler. This unit is in closed circuit with the hydraulic coupling and is filled with oil over and above that required for the coupling. The temperature of the fluid is kept at 120° F.

The unit is equipped with a thermostat in the oil line that receives hot oil from the coupling. The thermostat is connected in closed circuit with an electric motor, which in turn operates a set of louver dampers in the unit. The louver dampers serve to control the amount of cold air being drawn through the cooling coils of the unit by a fan. The fan operates at constant speed, continuously drawing cold air through the coils. The temperature of the oil is controlled by the thermostat in the hot oil line activating the electric motor, which in turn regulates the louver dampers so that the proper amount of cold air passes over the cooling coils to maintain the temperature of the oil at 120° F.

The Homer mine ventilation-air heating plant operated quite successfully during the winter of 1949-50. Control of temperature of the air entering the mine was maintained close to 36° F. No serious difficulties have been experienced with the automatic devices.

Interior - Bureau of Mines, Pittsburgh, Pa.

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